small area near McCoy, Colorado, and in a large region in east-central Nevada indicate that at least eight major marine and paralic faunal assemblages occur in rocks of Pennsylvanian and Permian age. The eight recognized major faunal groups are: textulariid, fusulinid, coral, productid-*Composita*, chonetid, *Heteralosia*, *Nuculana*, and *Euphemites* faunas. The textulariid, fusulinid, coral, productid-*Composita*, and chonetid faunas required a salinity close to 35°/oo. The textulariid fauna probably lived at a depth of 50–70 m. and perhaps deeper; fusulinid fauna, 20–50 m.; and coral fauna, 10–30 m. The productid-*Composita* and chonetid faunas both may have lived at a depth of 4–10 m., but they had different energy requirements. The *Heteralosia*, *Nuculana*, and *Euphemites* faunas occupied very shallow-water environments with salinities different from 35°/oo.

Overlap of faunas appears to have been a more common occurrence in the Colorado area than in Nevada because a greater inclination of the sea floor in Colorado allowed maximum development of different faunas to take place in areas close enough together to permit considerable faunal mixing. Geographic distribution of contemporaneous faunas indicates that inclination of the Colorado sea floor generally was about 10 m./km., whereas the inclination of the Nevada sea floor generally was about 1 m./km.

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Geochemical Prospecting—A Critical Review

A recent visit to the Soviet Union confirms impressions from the literature that Soviet geochemists continue to be the most active in geochemical prospecting technology. The All Union Scientific Institute of Nuclear Geophysics and Geochemistry in Moscow has the prime responsibility for research and development of near-surface geochemical prospecting for practical application as a rapid reconnaissance tool, especially in new areas and for stratigraphic traps, in support of geophysics and geology exploration. The major topics of investigation include: vertical migration mechanisms, radiometry, geomicrobiology, soil gas analysis, and gas logging.

In the United States, geochemical prospecting has had an erratic history of research and application, and although credited in whole or in part with some discoveries, it is not generally accepted as a commercially useful tool.

Successful application of near-surface geochemical prospecting requires (1) migration of hydrocarbons from the accumulation to the near-surface zone, (2) detection and identification of these migrated hydrocarbons in micro quantities, and (3) correlation of the observed near-surface distribution of these hydrocarbons with their subsurface source. Modern analytical methods for detecting micro quantities of hydrocarbons in rocks, soil, or soil gas samples are accurate and definitive. Factors complicating the use of geochemical prospecting involve the vertical migration process with the associated complex environmental productive zones, non-commercial occurrences, and intervening source rocks. Field tests indicate that where hydrocarbons succeed in reaching the near-surface zones, they usually do so in the form of seeps of restricted areal extent even at the micro concentration level.

From the initial work of United States and Soviet geochemical investigators 25 years ago, there has developed a sophisticated geochemical technology now making important contributions to petroleum exploration through source bed evaluation, crude oil correlation, formation water analyses, and origin and migration investigations.

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Structural Features of the Canadian Shield

The paper is accompanied by a sketch map showing the main structural and orogenic features of the Canadian Shield. Three main types of structural patterns are distinguished. Regions characterized by high-grade metamorphism or granitic intrusions present swirling and circular structures of extremely complex pattern and relatively little topographic relief. Areas of low grade, folded Proterozoic rocks form linear belts of generally more pronounced relief. Areas of flat or gently folded cover rocks of Proterozoic age form broad sheets of low relief except where cut by diabase sills. The various types of structures found in the exposed Shield may be expected to continue beneath the Phanerozoic cover.

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Depositional Environments of Some Cretaceous Sediments, Rocky Mountain Foothills, Canada*

Excellent exposures of Upper Cretaceous rocks in the central Foothills of Alberta reveal a lateral and vertical succession of marine shale, littoral and near-shore sandstones, and lagoonal to deltaic sediments. The interpretation of the depositional environments is based on comparisons with Recent sediments and on various physical criteria such as areal patterns, structures, and textures. In addition, paleontological data also provide useful information. The intertonguing of deposits records shifting shorelines related to the slowly regressing sea. Delineation of the ancient shorelines suggests areas in which potential reservoir rock may have formed and is important in future petroleum exploration.

Several units are interpreted as having formed in the transitional environment. Some of the sandstones, particularly those of the Cardium formation, are similar to those associated with barrier islands and represent the littoral and upper part of the epineritic environments. The sandstones are finely laminated, show reworking by organisms, and generally are well sorted. They have a linear distribution, extending for hundreds of miles along the Foothills. Associated with those sand bodies are carbonaceous sediments believed to represent lagoonal and marsh deposits. They include coarse-grained sandstone that presumably formed in stream channels, suggesting the presence of a deltaic complex. The abundance of carbonaceous debris and thin coal seams attest to widespread and recurring swamp conditions.

The marine shales are separated into several types, each characterizing a specific zone of deposition. Those formed in an oxidizing environment, presumably above wave base, contain glauconite and siderite. Shales formed below wave base were in a reducing environment that favored the development of pyrite and the diagenetic alternation of calcite to dolomite.

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Identification of Clinopyroxenes by X-Ray Diffraction and Optical Methods

* Published by permission of the director of the Geological Survey of Canada, Department of Mines and Technical Surveys, Ottawa.

The composition of common clinopyroxenes may be defined by measurement of the optical properties $2V_z$ and β. The mole-per cent composition thus obtained differs from that obtained by chemical analysis and for some varieties there is no reliable correlation between the optical properties and the chemical composition. For a diopside from Oka Complex, Quebec, the optical properties ($2V_z=56°$, $\beta=1.685\pm.001$) gave 48.1:41.9:10:0 for the Ca:Mg:Fe ratio, using the best curves available (Hess 1949), and the chemical analysis revealed the ratio 49.4:45.4:5.2.

We have applied optical properties to the determination of Ca:Mg:Fe ratio in various clinopyroxenes and we have observed the following degree of error by referring the composition determined by optical properties with that determined by chemical analysis

1. Diopsides-hedenbergites (mean value of error for 17 specimens) Mg:8.2 Fe:5.8 Ca:4.8
2. Augites (mean value of error for 7 sepcimens) Mg:3.6 Fe:4.5 Ca:3.6
3. Ferro-augites (mean value of error for 7 specimens) Mg:6.0 Fe:6.1 Ca:3.4

It may be possible to obtain a better definition of that composition by exact intensity measurements of X-ray powder diagrams. Several measures on a group of six clinopyroxenes reveal this possibility.

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Geochemistry of the Sulphur Isotopes and Petroleum Exploration

Early investigations of the sulphides and sulphates in sedimentary rocks showed wide variations in the abundance of the sulphur isotopes. More recent investigations of petroleum and related materials show that these also vary markedly in their sulphur isotope content. It is now known that the biological sulphur cycle and in particular the bacterial reduction of sulphate is largely responsible for the fractionation of the sulphur isotopes in nature.

In the interpretation of the sulphur isotopte distribution data in terms of natural processes and earh history, it is essential that we know the base levels of isotope ratio from which fractionation began as well as the extent of fractionation which can occur in any process. Since petroleum is usually formed in a marine or marine-like environment, it is important that we know the sulphur isotope ratio of the sulphate in the oceans and how this ratio has been changing throughout geological time. An extensive study of evaporites in various sedimentary basins has been carried out by Thode and Monster (1962). It is clear from their results that the sulphur isotope ratio of the evaporites reflects the environment and sulphur isotope ratio in the basin at the time of deposition. On the assumption that the lowest S^{34} enrichment found in the evaporites of a given geological period from various sedimentary beds will give the closest approach to the value of the ocean sulphates of the period Thode and Monster have determined the S^{34} content of the ancient seas. The results clearly show that the sulphur isotope ratios of the oceans have changed with time in a complex but cyclic fashion.

The sulphur isotope ratios of petroleum samples also reflect these changes. In particular, these ratios appear to reflect the isotope level and environment of the basin during the time of petroleum formation. However, the petroleum ratios are displaced from those of the contemporaneous evaporites by about $15°/_{oo}$ which is the fractionation to be expected in the bacterial reduction of sulphate. These results suggest that it is the reduced sulphur which becomes incorporated into the petroleum and that ocean sulphate, or sulphate of a large inland sea, is the source of petroleum sulphur. It is not surprising, therefore, that the pattern of isotope distribution in petroleum and related materials in non-marine sediments is completely different from that of those of marine origin. These results will be discussed from the point of view of petroleum exploration.

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Fluvial Processes as Interpreted from Ancient and Recent Fluvial Deposits

Detailed outcrop studies of fluvial deposits in the Missourian of Oklahoma and the Atokan of the Arkoma basin have revealed a systematic vertical variation in grain size, sedimentary structures, bedding characteristics, and morphology of sedimentary units. The frequency with which this "ideal" sequence is developed suggests a common process in the deposition of many of these fluvial sandstones. The "ideal" vertical sequence is as follows: (1) a lowermost festoon cross-bedded zone related to sand wave and (or) "dune" transport; (2) a parallel laminated zone deposited in low amplitude sand waves or in a plane bed; (3) a fine-grained symmetrical ripple zone containing sediment formerly transported in suspension; and (4) a laminated clay and fine-grained sand zone deposited from suspension (commonly outside of the fluvial channel). This sequence has been found in both Recent and ancient fluvial deposits.

Flume and river studies have demonstrated that specific sedimentary structures are directly related to sediment transport and the dynamics of open channel flow. Sedimentary structures in the ancient sandstones of the study area were related to bedforms described from Recent channels. Furthermore, additional information on the morphology of the fluvial channels was obtained from an analysis of the thickness and distribution of specific zones.

The grain-size distribution of the fluvial sands of the study area suggests an upward decrease in energy. Both the mean and maximum grain size decrease upward, and the sediment is progressively more poorly sorted upward. These changes are directly related to variation in the type and size of the sedimentary structures. Discontinuities resulting from successive floods were identified by abrupt changes in grain size and (or) in the sequence of sedimentary structures.

The "ideal" vertical sequence, as given is commonly encountered in the field. This suggests some common underlying cause. This study illustrates that use of the flow regime concept, together with an understanding of river hydraulics and channel behavior, can provide a better insight into fluvial sedimentation.

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Telluric Currents and Their Use in Petroleum Exploration

Telluric currents are electrical currents in the earth induced by ionospheric disturbances. They are always present and contain all frequencies, from cycles per day to cycles per second.

The currents and their associated magnetic fields (micropulsations) provide sensitive indications of changes in electrical conductivity in rocks, such as